Climate, Weather, and Water Science

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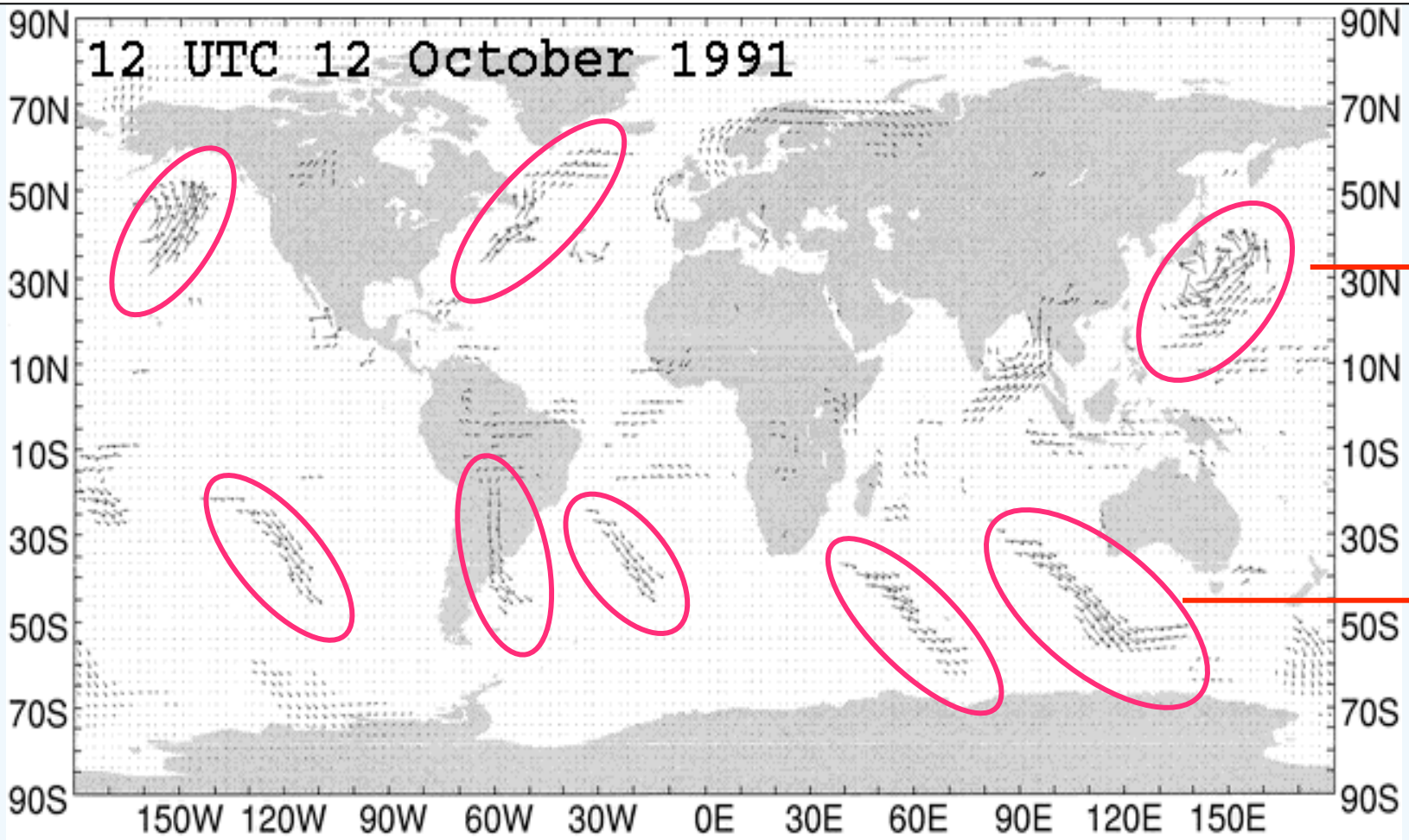
Landfalling Impacts of Atmospheric Rivers: From Extreme Events to Long-term Consequences

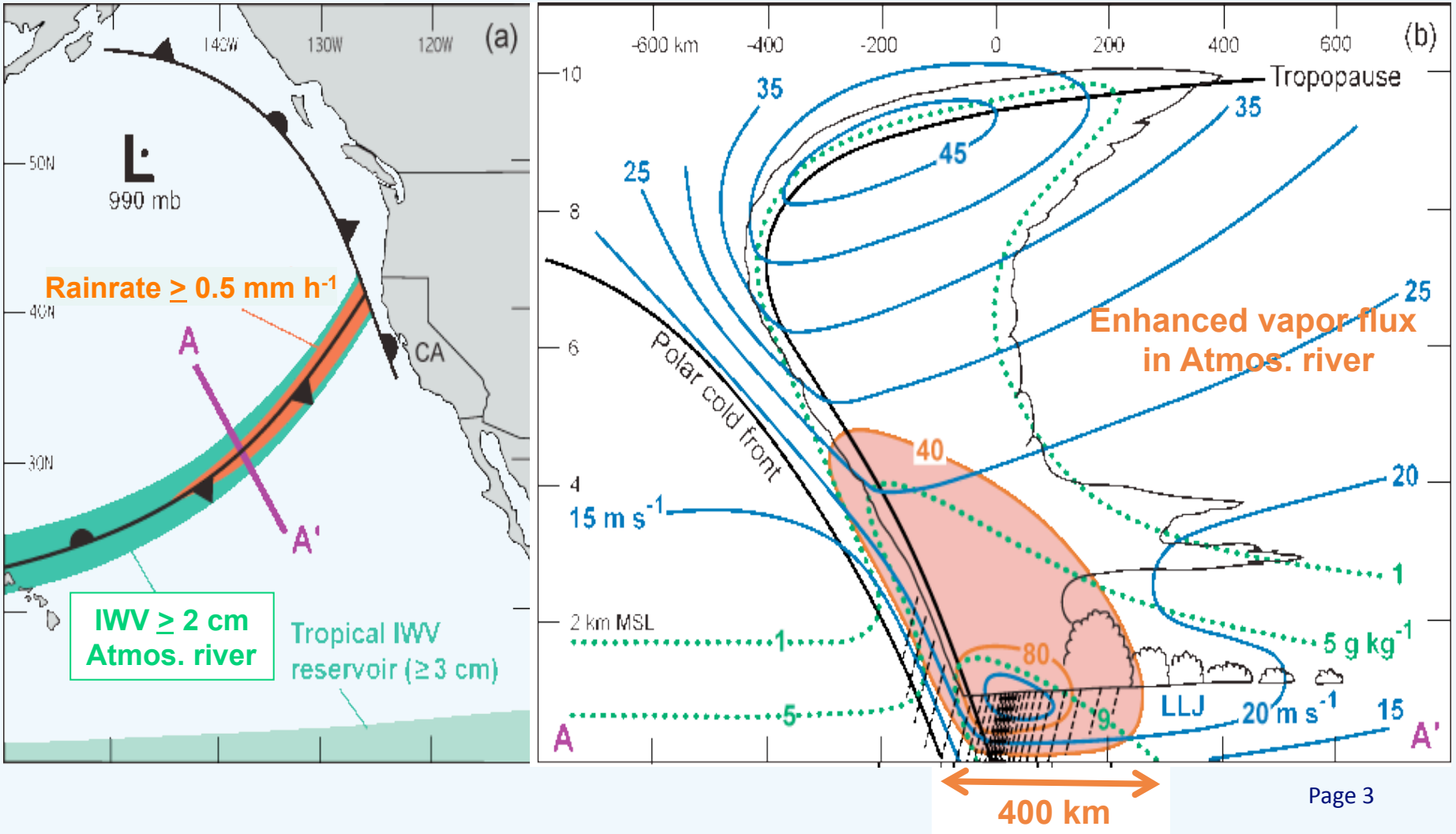
Zhu & Newell (1998) concluded in a 3-year ECMWF model diagnostic study:

1) 95% of meridional water vapor flux occurs in narrow plumes in <10% of zonal circumference.
2) There are typically 3-5 of these narrow plumes within a hemisphere at any one moment.
3) They coined the term “atmospheric river” (AR) to reflect the narrow character of plumes.
4) ARs constitute the moisture component of an extratropical cyclone’s warm conveyor belt.
5) ARs are very important from a global water cycle perspective.



Observational studies by Ralph et al. (2004, 2005, 2006) extend model results:

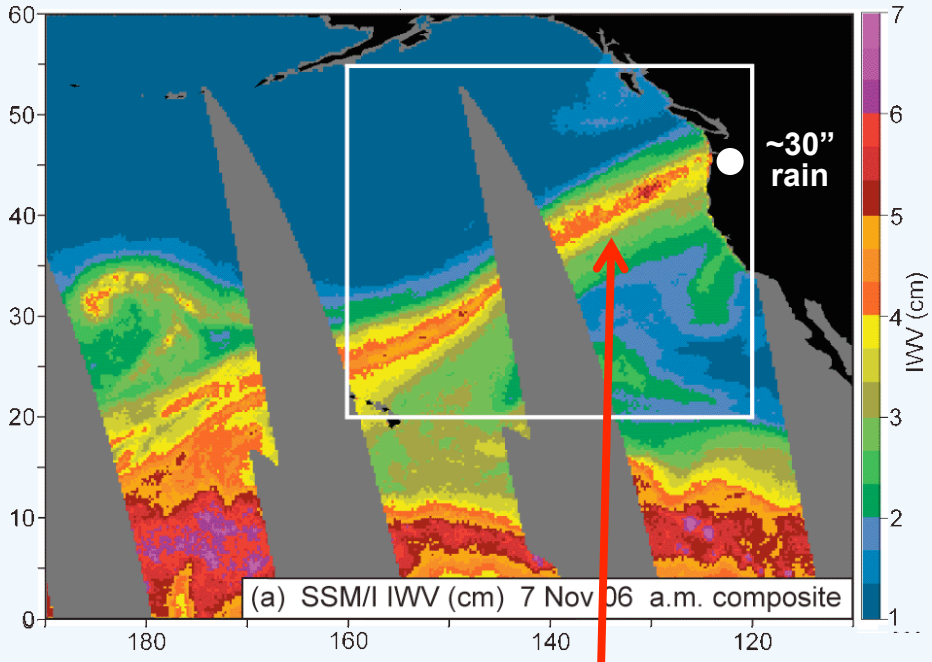
1) Long, narrow plumes of IWV >2 cm measured by SSM/I satellites considered proxies for ARs.
2) These plumes are situated near the leading edge of some (but not all) oceanic polar cold fronts.
3) P-3 aircraft documented strong water vapor flux in narrow (400 km-wide) ARs; See section AA'.
4) Airborne data also showed 75% of the vapor flux was below 2.5 km MSL in vicinity of LLJ.
5) Moist-neutral stratification <2.8 km MSL, conducive to orographic precip. boost & floods.



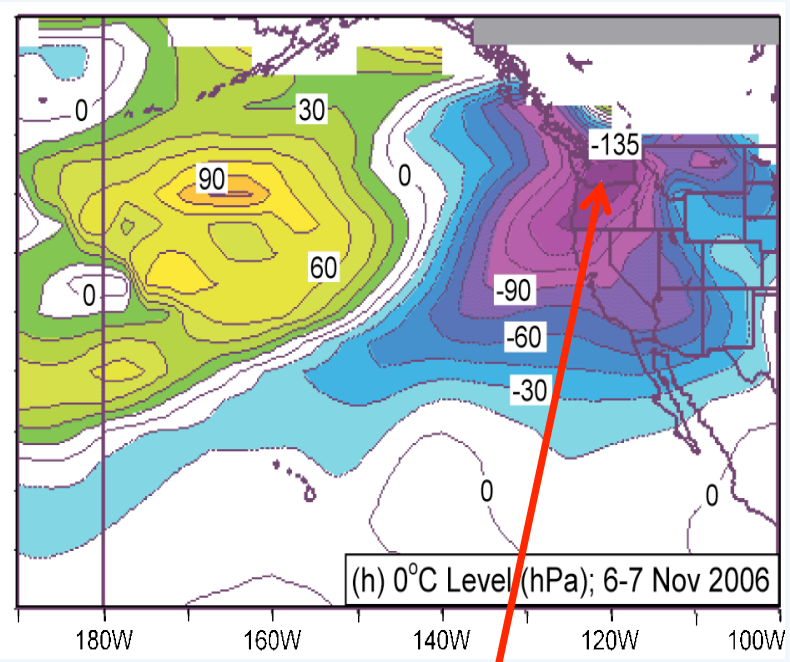
Pacific Northwest Landfalling AR of early November 2006

Neiman et al. (2008a)

SSM/I satellite imagery of integrated water vapor (IWV, cm)



Global reanalysis melting-level anomaly (hPa; rel. to 30-y mean)

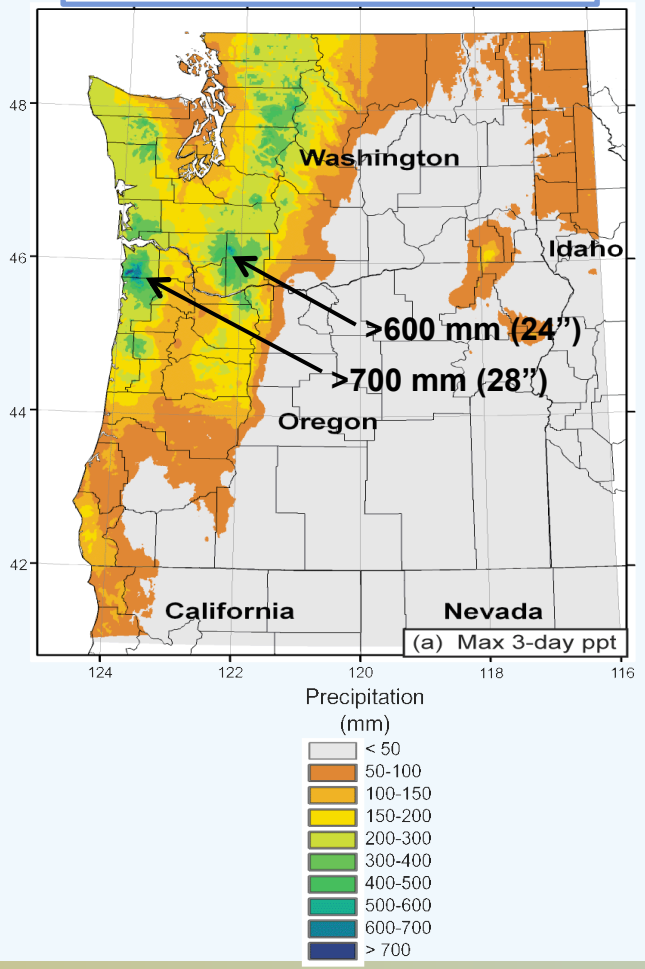


This AR is also located near the leading edge of a cold front, with strong vapor fluxes (as per reanalysis diagnostics)

Melting level ~4000 ft (1.2 km) above normal across much of the PacNW during the landfall of this AR

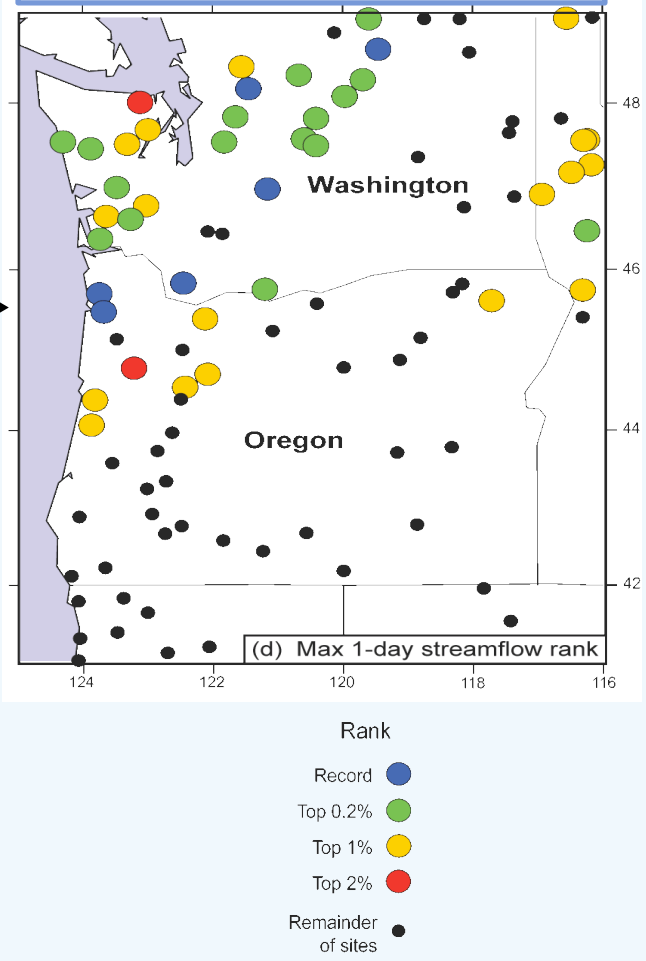
Hydroclimatic analysis for the AR of 5-9 November 2006

Greatest 3-day precip. totals during the period between 5-9 Nov. 2006



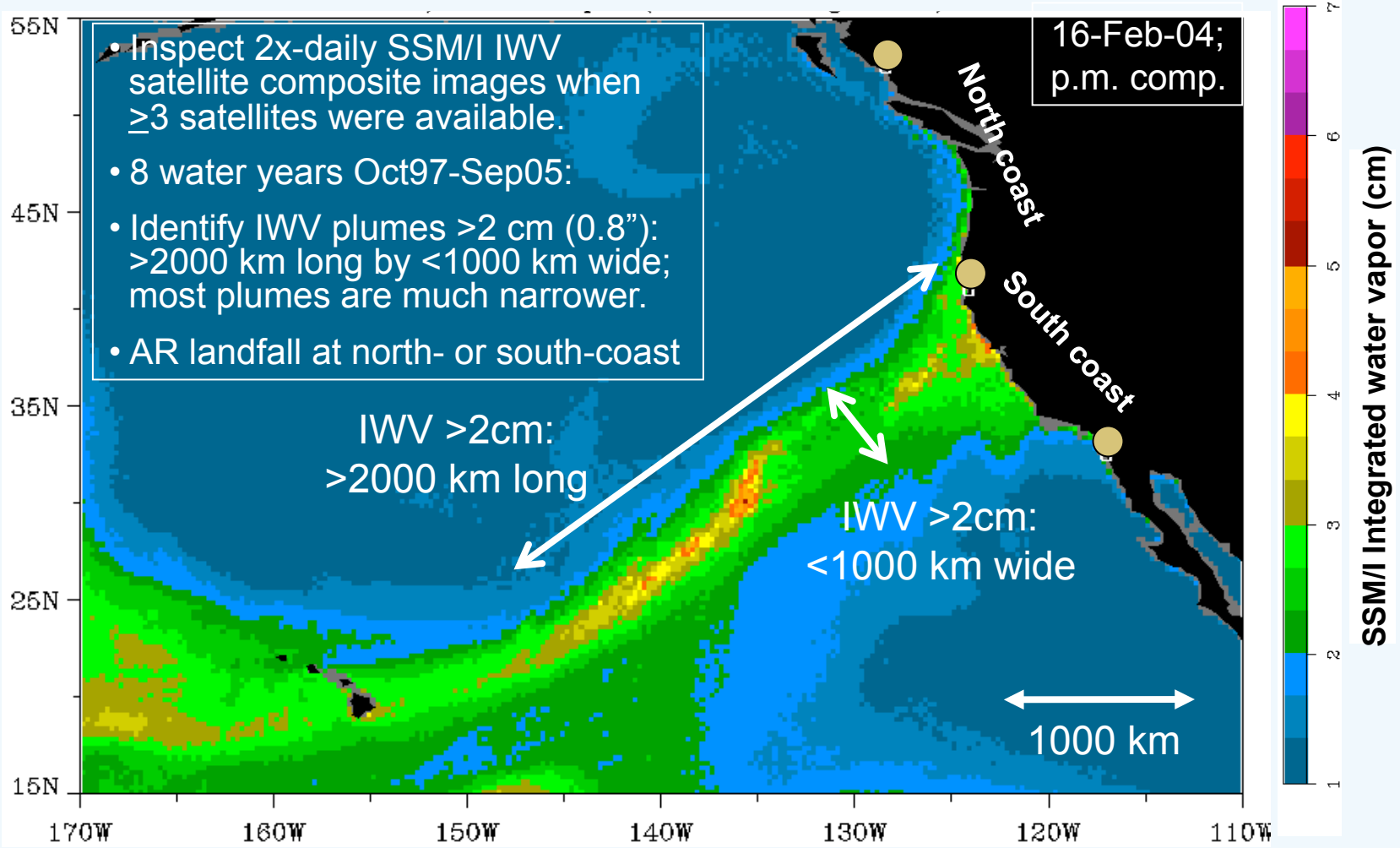
plus high melting level equals

Historical Nov. ranking for the max. daily streamflow between 5-9 Nov. 2006

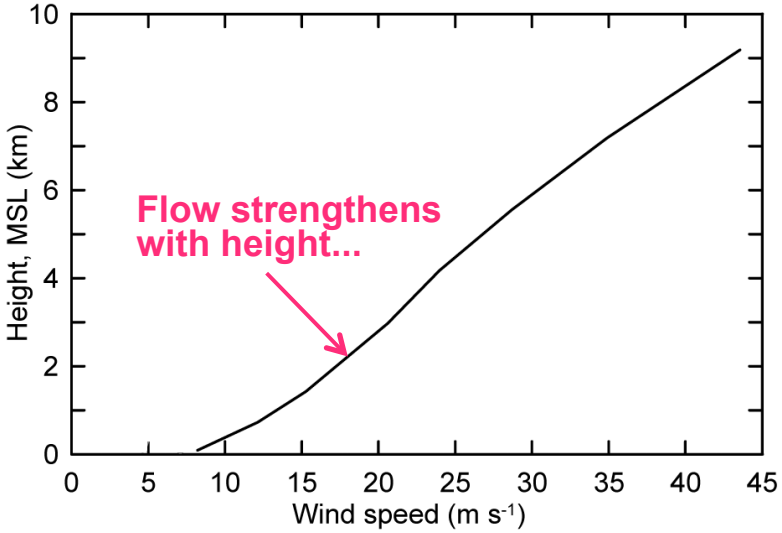


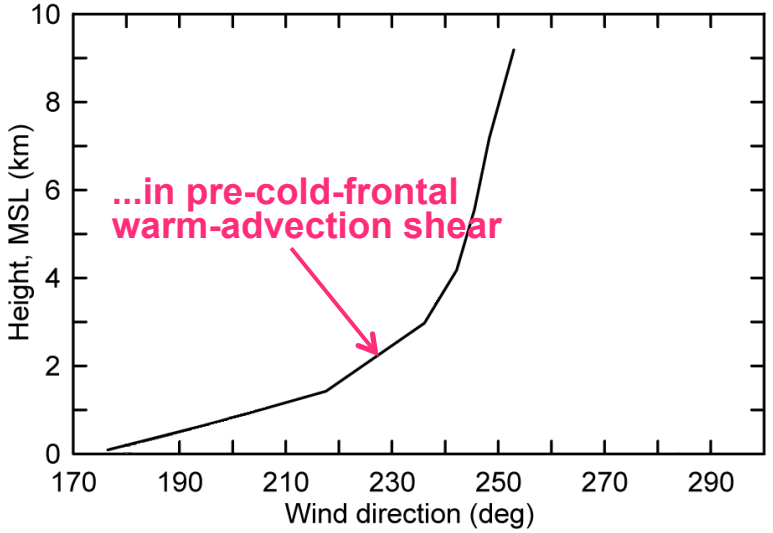
Given these results: **What are the long-term hydrometeorological impacts of landfalling ARs in western North America?** Neiman et al. (2008b)

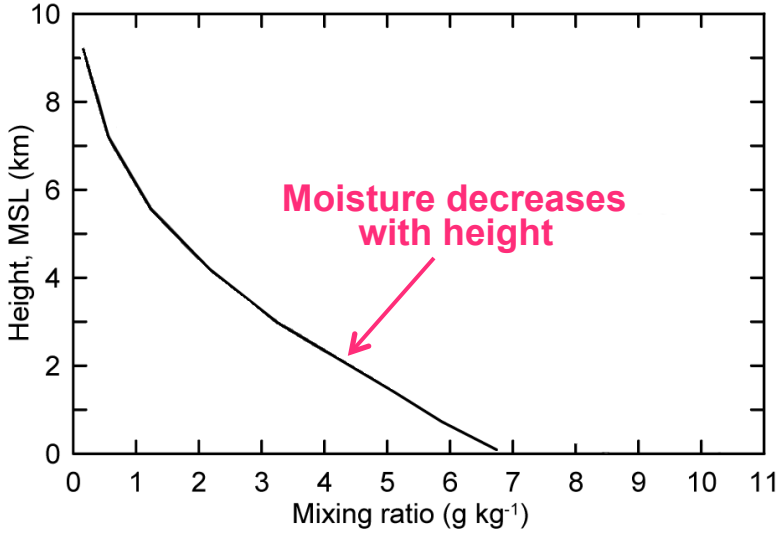
Approach: We developed a methodology for creating a multiyear AR inventory.

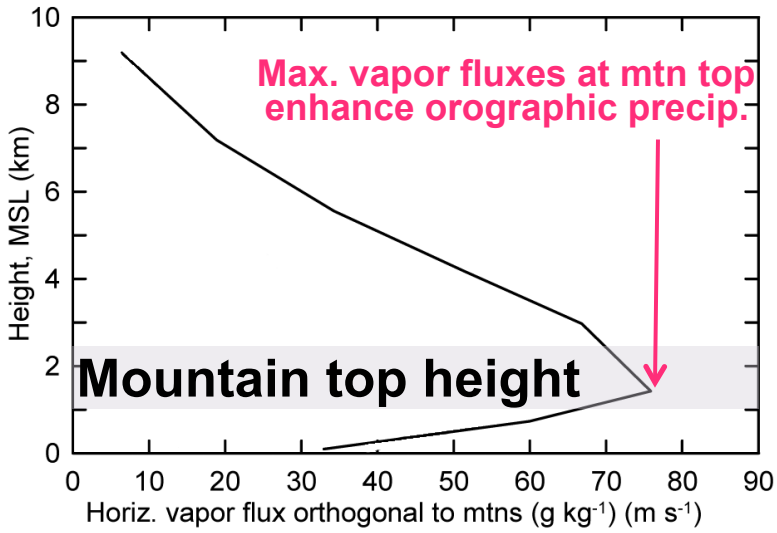


Composite Winter Global Reanalysis Soundings



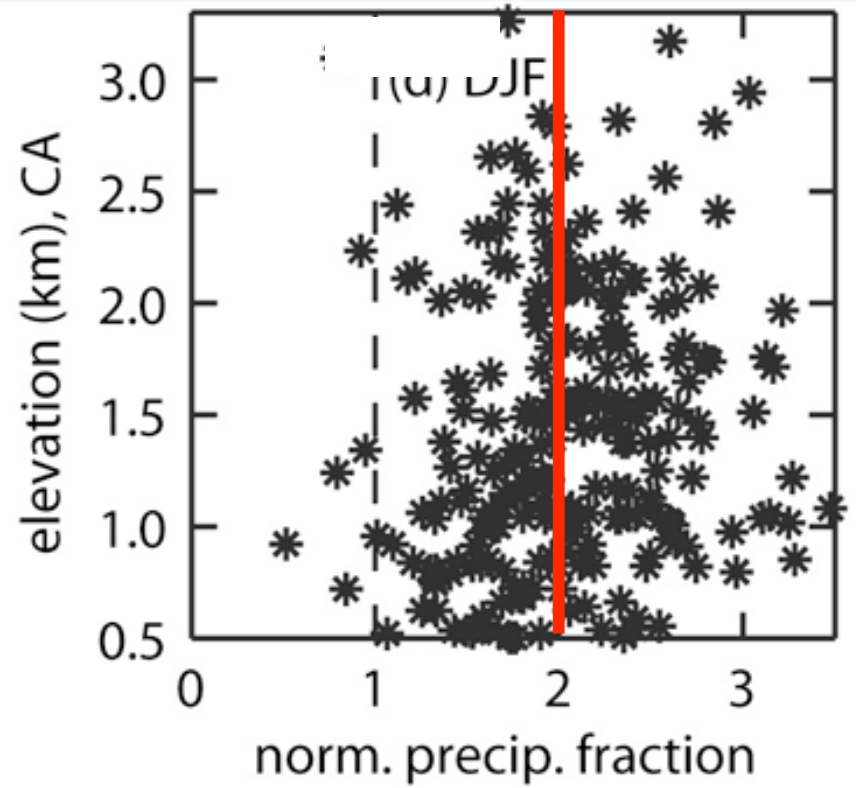






Normalized Daily Precipitation During Winter

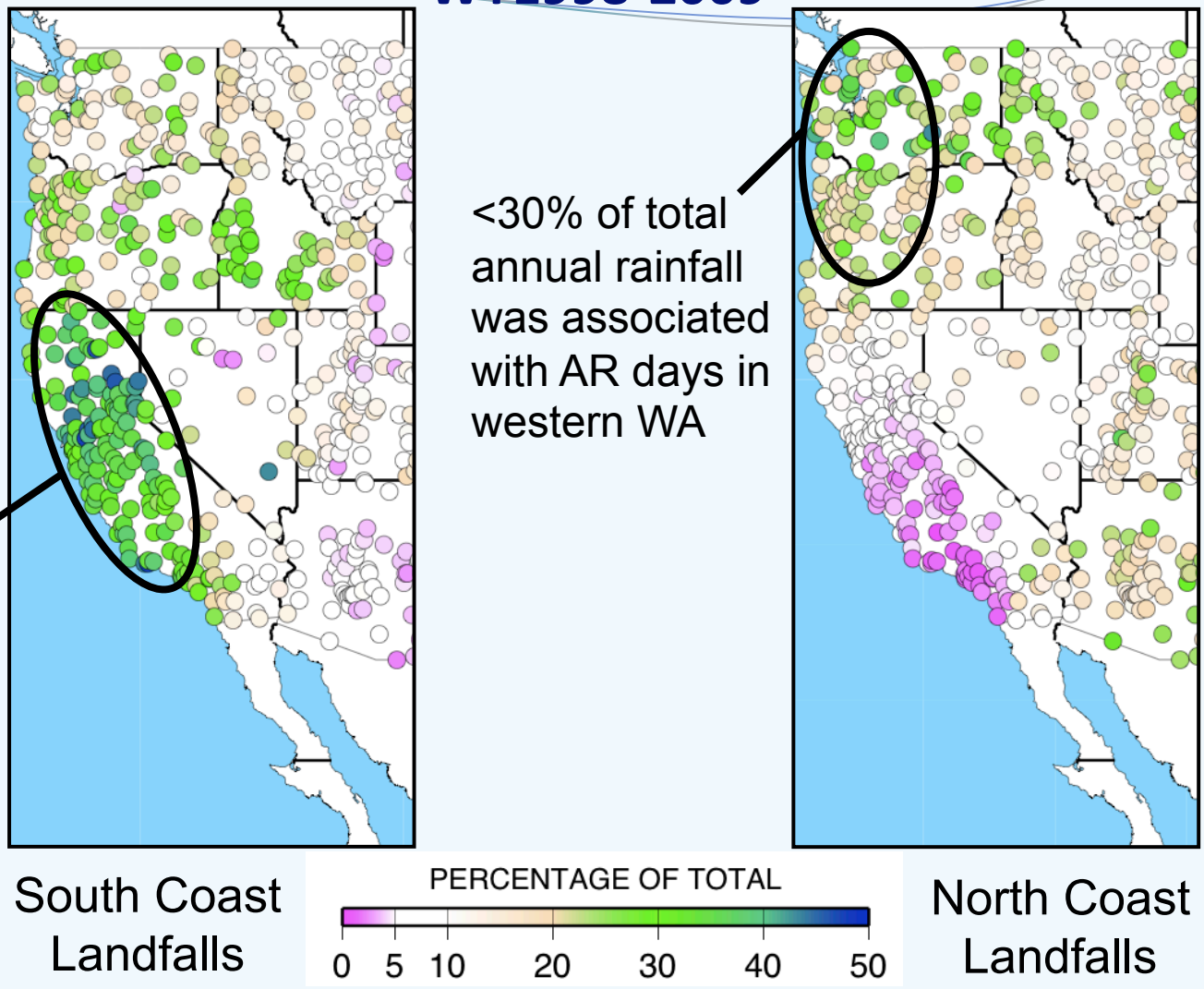
Compared to the average of all precipitation days in the West Coast states (observed by rain gauges), those days associated with landfalling Atmospheric Rivers produced twice the average precipitation.



Similar outcome for the change in daily snowpack for high elevation sites, based on snow pillow observations.

Contribution of AR Days (0 and +1) to Total Precipitation WY1998-2009

(Courtesy of M. Dettinger at Scripps)



Concluding Remarks

- ARs are corridors of enhanced water vapor flux.
- ARs are anomalously warm with high freezing levels.
- ARs produce extreme rainfall, flooding, and debris flows in the western U.S.
- ARs are critical for long-term water supply and planning – especially in California.

AR debris flow aftermath on the White River, OR

Folsom Reservoir, CA

Emerging Research Spawned by AR Findings

- Exploring sources/sinks of water vapor in ARs via trajectory analysis.
- Identifying ARs as objects in forecast models and SSM/I satellite imagery.
- Assessing the predictability of ARs, from the large scale to watershed scale.
- Investigating impacts of climate change on AR intensity & frequency at landfall.